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1 April 1996 through 31 March 1997

RICHARD STARR, CO-PI

SMALL SATELLITE TECHNOLOGY INITIATIVE (SSTI)

R. Starr is the leader of the science team for the X-Ray Spectrometer (XRS) which will fly on-board the SSTI Clark satellite. This XRS will fly small room-temperature, solid-state detectors that have never been flown in space before. In addition to testing this new technology, this instrument is designed to detect X-rays from solar flares and gamma-ray bursts in the energy region from about 1 keV to 100 keV. The XRS has been through environmental testing and was delivered for spacecraft integration in July, 1996. The Clark spacecraft is scheduled to be launched in March 1997 and the XRS will collect data in orbit continuously for the next three years. R. Starr has continued to support integration and test throughout this period. A paper entitled, "The X-Ray Spectrometer for the Clark Mission" has been accepted for publication.

PLANETARY PROGRAM

Near Earth Asteroid Rendezvous (NEAR)

The NEAR spacecraft was launched in February 1996 and will rendezvous with the asteroid Eros in February 1999. R. Starr has supported all phases of design, test and integration of the X-Ray/Gamma-Ray Spectrometer (XGRS). During this time period he has analyzed flight data from both the gamma-ray and x-ray spectrometers in order to verify operations and has continued ground calibrations of the gamma-ray spectrometer using the flight spare instrument.

Planetary Instrument Definition and Development Program (PIDDP)

Under the PIDDP program R. Starr has been part of a team that has as its goal the development of new x-ray and gamma-ray detectors for space flight experiments. The focus has been on small room-temperature solid-state detectors such as mercuric-iodide, cadmium-zinc-telluride, and silicon detectors.

CARL WERTZ, PI

Gamma-Ray Line Shifts from Energetic Ions

Previously developed codes that calculated the gamma-ray line profiles from ions at rest which are excited by light projectiles such as protons or alpha particles were

modified to calculate the line profiles when heavy ion projectiles strike ambient hydrogen and helium nuclei. Applications to both the broad component of lines in solar flares and to the broad lines of carbon and oxygen which have been detected by **COMPTEL** in the direction of the Orion nebula are in progress.

The PI acted as liaison between the students at Goddard taking part in the summer research program and the administration at The Catholic University of America which issued pay checks, reimbursed travel, and carried out other fiscal services.

FRED LANG, POST DOC

Summer Student Administrator

The Laboratory for Astronomy and Solar Physics (**LASP**) funded the Post Doc to conduct their Summer Student Program for 1996. The Post Doc recruited students and maintained a file of applicants. He solicited positions within the **LASP**, arranged interviews for the students with prospective mentors at Goddard, and assisted with matching applicants with prospective tasks. He arranged for students to be paid through this grant. He provided guidance, advice, and sympathetic ears for the students and their mentors.

HESSI

The High Energy Solar Spectrographic Imager (**HESSI**) is a solar satellite that has been proposed for the coming solar maximum. It builds on the technological heritage developed with the High Energy Imaging Device (**HEIDI**) that has been the primary focus of most of the work done by the Post-Doc for the past 7 years. **HESSI** is currently under consideration for a new start by **NASA** Headquarters.

The post doc has been the manager for the **HESSI** Grid Characterization Facility (**GCF**), which was originally developed for characterization of the **HEIDI** grids. The post doc has carried out measurements of prototype grids for **HESSI**. He has supervised the installation and integration of a laser ranger system into the **GCF** that permits more precise measurements of grid characteristics. He supervised the production of a "User's Guide" to the **GCF** and has produced a document containing a description of the error considerations for the facility. He has worked with other **HESSI** investigators to plan upgrades to the **GCF** that are currently under way.

OVRO

The post doc has begun work on data from microwave-emitting sources observed with the Owens Valley Radio Observatory (**OVRO**) Solar Array. A collaborator has gathered data from nearly 300 suspected solar flares observed with **OVRO**. The post doc is working on modifications to analysis software to be used to determine the

sizes, separations, and multiplicities of spatial components as a function of time, frequency, and polarization. Completed work has focused on upgrading the IDL widget front-end to the analysis program.

TAMMY DICKINSON, RESEARCH SCIENTIST 1

Magnetic Properties of Meteorites

This task is in cooperation with Peter Wasilewski at NASA Goddard Space Center. During the past year I have worked on two manuscripts with Peter. The first is entitled "Shock Magnetism in Fine Particle Iron" and describes our work on the effects of shock on the magnetic properties of chondrules. In this paper we develop a preliminary framework for understanding the magnetic properties of fine-grained Fe particles and describe initial experiments on shock effects. We present the first characterization of pre- and post-shock magnetic properties and the first characterization of the transformation remanent magnetization associated with the face-centered-cubic to body-centered-cubic transformation in fine particle Fe spheres. We show that the transformation remanent magnetization is nearly in the same direction as the ambient magnetic field during shock, but that the remanence intensity is 1-2 orders of magnitude less than that expected for a thermoremanent magnetization during cooling through the Curie temperature. This paper was submitted to Meteoritics and Planetary Science in April 1996. We recently received the reviewer comments. I am currently working on revising this paper and would expect it to be published during the first half of 1997.

Peter and I are also currently working on a paper entitled "Magnetic Contamination" which describes the various effects that contamination have on the magnetic properties of chondrules and meteorites as a whole. The magnetic study of meteorites is hampered by the unknown extent of magnetic contamination after the meteorite reached the earth's surface. It is not uncommon to use a hand magnet as a diagnostic aid in determining if a sample is a meteorite or a terrestrial rock. We have evaluated the effect of contamination by a hand magnetic on a variety of meteoritic material. We also show how remanence acquisition curves can be used as a magnetic contamination curves. We plan on submitting this manuscript to Meteoritics and Planetary Science in January 1997. Peter and I are planning on submitting an abstract to the Lunar and Planetary Science Conference on this research.

In addition, Peter and I are working on a project that will help to interpret the magnetometer data from the NEAR spacecraft which will measure the magnetic signature of the asteroid EROS. This project will realistically address for the first time the magnetic signatures of meteorites and thereby provide a model for interpreting the NEAR spacecraft magnetometer data. We have received permission

from the Smithsonian Natural History Museum to measure the magnetic properties of three of their largest meteorite specimens. Arrangements have been made to have the first of these samples transported to Goddard Space Flight Center on January 6, 1997. The measurements should be completed by January 8, 1997. Peter and I are planning on submitting an abstract to the Lunar and Planetary Science Conference on this research.

Experimental Studies of Highly Reduced Meteorites

This project is a collaboration between Tim McCoy of the Smithsonian Natural History Museum and Gary Lofgren of the Johnson Space Center. During the past six months, we have been having experimental difficulties producing reduced charges at low temperatures (1000-1200°C. After considerable trial and error and a little luck it appears that we have solved these experimental problems. We have completed a new set of experiments on powdered Indarch (an enstatite chondrite) under reducing conditions at temperatures between 1000 and 1450°C. Tim and I will begin analyzing these samples on the electron microprobe at the Natural History Museum in December 1996. We are planning on submitting an abstract on these data for the Lunar and Planetary Science Conference.

During the last year Tim and I wrote a manuscript entitled "Experimental REE partitioning in oldhamite: Implications for the igneous origin of aubritic oldhamite" describing the results of experiments I performed while a National Research Council Post Doctoral Fellow at the NASA Johnson Space Center. I am in the process of revising this paper based on reviewer and editor comments. The paper should be resubmitted this year and is expected to be published in *Meteoritics and Planetary Science* during the first half of 1997.

PAM CLARK, RESEARCH SCIENTIST 2

Support of NEAR X-ray Instrument during cruise

NEAR In-Flight calibration (96-98)

During the NEAR mission cruise phase (beginning in April 1996), Clark is supporting calibrations done for all five flight X-ray detectors (two solar monitors, three surface asteroid pointing detectors), including energy and intensity calibrations using a built-in source, and determination of instrument and sky background. Performance of hardware and software is being investigated, anomalies resolved, and instrument settings being finalized. Output from detectors is in reasonable agreement with theoretical models. The cosmic-ray induced background for proportional counters is higher than anticipated and is being compared to background from previous missions and being modeled as well. Measurements will be collected and reduced whenever the X-ray detectors are turned on. Some of this work will be

presented at the CHERBS conference in July, and a paper is in preparation.

Laboratory calibration (96-97)

Calibration of flight spares under vacuum is continuing at APL. End-to-end tests are planned with flight software on differentially filtered detectors under more controlled conditions. Attempts are being made to simulate the sun as a source by special filtering and setting of voltages on the laboratory X-ray generator. More stringent calibrations will be performed on flight spare solar monitors, with longer integration times than previously possible.

Comparison of solar X-ray detector outputs (96-98)

During cruise phase of the NEAR mission, approximately 2 months worth of data has been obtained for the solar monitors, which have been turned on whenever calibration is performed on the detectors. During this time, solar spectra from 1 to 10 keV at solar minimum have been obtained. Three C-level flares have been recorded, and numerous B sub-flares. It has been possible to determine the 'detection limit' for both detectors. Results from the two solar monitors were compared to each other and to theoretical models for solar output, as well as to GOES (solar satellite) output. Actual and predicted output were found to be in good agreement, once cosmic-ray induced background was subtracted from the proportional counter. GOES output was consistently correlated with NEAR solar monitor output. The higher spectral resolution of the PIN detector made it possible to observe line structure during flares. In order to make these data particularly useful, NEAR and other solar satellite data will be compared during the NEAR mission Earth fly-by in 1997, and the relationship between various solar X-ray instrument measurements will be empirically quantified. Discrepancies, primarily due to differences in filters and absorbing gases in the detectors, can be successfully removed by modeling instrument response functions. In addition, comparisons are being made to solar monitor datasets from the Apollo 15 and 16 solar monitor, which was a pinhole solar monitor detector flown during mid-cycle. Improvement in details of solar models are being made from solar monitor observations.

Because accurate modeling of solar output is crucial for quantitative measurements of surface compositions, efforts will be made to improve modeling of the solar spectrum even further. Currently, solar spectra, with best available line and continuum models (Kreplin et al, 1977) can be calculated using readily available software for given temperature and emission ratio regimes here at Goddard (Thomas and Schwartz, personal communication, 1994), or in other centers of solar physics research (Garcia and Donnelly, personal communication, 1993). Solar spectra of the soft X-ray region, derived from the best available models, as well as published examples of average spectra for representative levels of solar output, are being folded through GOES instrument response function. A comparison of spectra derived from a range

of differential emission inputs and GOES observations has been made, and temperatures of the resulting spectra calculated using algorithms currently in use for GOES data, to determine how well GOES temperature predictions match distributions from the best multi-temperature spectral input model. The goal here is to provide increased knowledge of the soft X-ray (1 to 10 keV) region of the solar spectrum and improved criteria for selection of detectors and wavelength ranges for future missions in space physics and other related disciplines. Some of this work will be presented at the CHERBS conference in July, and a paper is in preparation.

Development of new instruments, analytical tools, and applications for future missions

Preliminary study for development of an in-situ combined X-ray Fluorescence/X-ray Diffraction Instrument

Preliminary work is being done in the laboratory to develop a portable X-ray diffractometer/X-ray fluorescence system as an in-situ instrument for future landers or a field instrument. The system will use a low current broadband X-ray generator systematically set at series of low voltages and optimally placed small solid state detectors. Experiments will be done to demonstrate that the X-ray diffraction portion can provide adequate signal and resolution in diffraction spectra to characterize mineral components of soils. This is the first time this has been attempted with a broadband source and detection of mineral crystal line spacings using energy rather than angular term in the Bragg equation.

X-ray production modeling

Improvements in generality have been made in X-ray production model software. Generation of anticipated spectra has been done for a more extensive range of possible compositions and flight trajectories for future proposed Mercury missions, including the ESA Cornerstone mission, and Discovery comet/asteroid encounter missions, and a lunar orbiter mission. Two papers are in press, and two in publication as a result of this work. (See publications.)

Comparison of Planetary Composition Derived from X-ray, Gamma-ray, and other Instruments (96-98)

X-ray, Gamma-ray, and visual spectral imaging instruments will all be flown on the NEAR mission. Measurements from all three instruments will be used to derive iron abundances. Until then, the Moon continues to be the only planet from which remote geochemical (Gamma-ray) and mineralogical (spectral reflectance) observations are available. Maps derived from these two different datasets, directly from the Gamma-ray data and by inference from the spectral reflectance, have shown striking differences. Unfortunately, the gamma-ray derived iron map covers about twenty

percent of the lunar surface, all of it near the equator. The newly published Clementine spectral reflectance derived so-called 'iron' map has 90% coverage. The Clementine map shows a Moon which had a far simpler history of crustal formation followed by mare volcanism. From careful pixel by pixel study of Clementine spectral reflectance derived albedo map, so-called 'iron' map, and the Apollo gamma-ray derived iron map, we have determined that the gamma-ray derived map accurately reflects both geological and sample data available for the moon. Our findings also indicate that the spectral reflectance derived 'iron' map is actually a combined albedo and composition map, and are in the process of producing a global lunar iron map, from careful calibration of the Clementine data with the Apollo gamma-ray iron data. This work not only has implications for the origin of the Earth Moon system, but also will be used to support the data reduction efforts for the XGRS instrument on the NEAR mission. Some of this work has already been presented at the last Lunar and Planetary Science Conference and DPS meetings. Further results will be presented at the next such conference. A paper of results of this study is being produced.

PRESENTATIONS/ABSTRACTS DONE

P.E. Clark and L. McFadden (1996) The lunar crust as case study: A comparison of iron data derived from geochemical and mineralogical remote sensing techniques, LUN AND PLAN SCI XXVII, LPSC.

P.E. Clark (1996) X-ray Spectrometers for Exploring the Moon and Mercury, Invited Talk, COSPAR 96, Birmingham, England, July, 1996.

P.E. Clark and L.A. McFadden (1996) The Moon as a case study, Part 2: Examining the relationship between surface chemical, mineralogical, and physical properties, DPS Meeting, Tucson, AZ, October, 1996

P.E. Clark and L.A. McFadden (1997) Will the real lunar iron abundances please stand up? NASA/GSFC, Code 690, Invited Poster Presentations, January, 1997

P.E. Clark and L.A. McFadden (1997) A new, calibrated global iron map for the Moon and its implications LUN AND PLAN SCI XXVIII, LPSC.

P.E. Clark and S. Floyd (1997) paper one for cherbs

P.E. Clark (1997) paper two for cherbs

PAPERS WORKED ON in Fiscal 96:

P.E. Clark and J. Trombka (1996) X-ray fluorescence experiments for future Mercury

orbital missions PLAN AND SPACE SCI (in press).

P.E. Clark (1997) X-ray Spectrometry for Remote Exploration of Mercury and the Moon ADV IN SPACE RES (in press).

P.E. Clark (1997) X-ray fluorescence from planetary surfaces: Modeling, data analysis, and future missions (in publication as NASA Technical Memorandum).

P.E. Clark, J.I. Trombka (1997) Remote X-ray Spectrometry for NEAR and Future Missions: Dealing with Solar Source Variation and Data Analysis (in publication as JGR paper).

P.E. Clark, L.A. McFadden (1997) Iron in the lunar crust, Part 1: A Comparison of Iron Data Derived from Geochemical and Mineralogical Remote Sensing Techniques (in publication as JGR paper).

P.E. Clark, L.A. McFadden (1997) A new lunar iron abundance map which best reflects sample and geological data (in preparation as Science paper).

PRESENTATIONS PLANNED for Fiscal 97:

First lunar global calibrated iron map, LPSC 97.

Analysis of first year of flight calibration data from NEAR, CHERBS 97.

Analysis of laboratory calibration data for NEAR X-ray instruments, DPS 97.

Dealing with solar source variation and background in NEAR X-ray data analysis, AGU 97.